R. A. Dyke, of the Weather Bureau forecast center at New Orleans, in reporting on the tidal conditions in that district during the final stages of the storm, said that "tides were highest on the 6th and 7th, but did not exceed 1.5 feet above normal from Pensacola to Apalachicola, and were lower than that elsewhere."

Warnings issued by the Weather Bureau in connection with the hurricane were ample and timely. On the morning of October 31, when the storm was a short distance to west-northwestward of Bermuda, the Bureau issued an advisory warning, and followed it by a second advisory message after receipt of the evening observations of the same date. On November 1 storm warnings were ordered up on the North Carolina coast, and on the 2d, extended to Charleston, S. C., with cautionary warnings covering the whole east coast to the southward. Full information of the movements of the storm on the 3d, accompanied by cautionary advices, were broadcast to all vessels and interests from the Bahamas to the Florida coast. The first order to hoist hurricane warnings was issued by the Jacksonville office on November 4, 1935, as follows:

Hoist 7:30 a. m. hurricane warnings Miami to Stuart and northeast storm warnings north of Stuart to Titusville. Tropical storm of small diameter but accompanied by hurricane winds has changed its course during the night and now seems to be moving in a westward direction over Bahama Island which is about 100 miles east of West Palm Beach moving about 7 to 10 miles per hour. While storm conditions continue to change direction, all interests on the southeast Florida coast between Miami and Stuart should take extreme precautions against high tides and hurricane winds. Further bulletins today will be issued at about hourly intervals. Caution advised all vessels off Florida coast.

The Jacksonville office thereafter issued such frequent advisory and other warning messages as were necessary, up to and including the 5th of the month, following which, during the presence of the storm in the Gulf, several daily advisories were issued from the office at New Orleans.

The new hurricane warning service gave widest possible distribution of all storm information throughout the Miami and other districts by radio, telephone, telegraph, press agencies, and posted bulletins. In addition, all other interested agencies gave the fullest possible cooperation throughout the life of the storm.

ON THE METEOROLOGICAL HISTORY OF THE HURRICANE OF NOVEMBER 1935

By H. R. BYERS

[Weather Bureau, Washington, December 1935]

The tropical hurricane during the first week of November 1935, described by Mr. Hurd in this issue of the REVIEW, had several outstanding abnormalities. Principal among these were the high latitude and late season of its origin, the singular distribution of the meteorological elements around it, its unusual path, and its odd dissipation in the Gulf of Mexico. An explanation of these phenomena, if at all possible, would be highly desirable; the observational data, particularly from the upper air, are insufficient for the type of detailed study necessary for a complete explanation, but a few features of the storm are here discussed which may partially account for the observed facts.

Formation.—The hurricane center developed on October 30 about 300 miles east of Bermuda. At that time, and indeed for 2 or 3 days previously, there was a trough of low pressure extending northeastward from the Lesser Antilles toward Iceland and toward a large, nearly stationary low-pressure center between Iceland and the Faroe Islands. From a first glance at the synoptic charts it would appear that the center developed from this trough, but closer observation and physical reasoning indicate that it did not do so. Observations show that the storm was to the west of the trough when first noted, and that at that time the entity of the trough was still preserved. It hardly is conceivable that the trough could have formed into the hurricane center without the resultant circulation destroying the trough character.

The air transport over the North Atlantic had been dominated during the preceding days by an abnormally large and stationary Icelandic cyclone. This brought behind it a strong outflow of polar air which settled in a large belt of high pressure to the north of Bermuda. This pressure distribution was accompanied to the south of the high-pressure center by easterly winds which, being originally of polar origin, had had a long fetch over the warm waters of this section of the Atlantic before they reached the vicinity of Bermuda. The wind and pressure structure, in fact, looked very much like the picture of the northeast trade winds, only displaced far to the north. This air must also have been unstable vertically, at least with respect to saturated air, since it was polar air being strongly heated from below incident to its passage over the warm water.

One of the most generally accepted views as t the origin of tropical cyclones is that they result from large-scale convection with its resultant converging winds which, under the effects of the deflecting influence due to the rotation of the earth, quickly develop a cyclonic circulation. It appears that the unusual conditions of the atmosphere, at the time and place of origin of this storm, were favorable for its genesis according to the above-mentioned hypothesis. That is, the presence of moist, unstable air caused convection over a wide area, with converging winds under the strong deflecting influence at that latitude.

The extra-tropical characteristics.—At the latitudes where this storm was located during its earlier history, the interaction of polar and tropical air currents dominates the circulation, particularly in the fall, winter, and spring. These air masses are integral parts of extra-tropical cyclones. At the latitude and season of development of this storm, it would almost inevitably involve in its circulation these various air currents. This should give the asymmetrical distribution of meteorological elements, such as precipitation, that is associated with the peculiar distribution of the air masses in an extra-tropical cyclone. The observational data of November 1, as shown by the weather map and vertical cross sections through the atmosphere along the coast of the United States, clearly indicate that this extra-tropical influence on the storm was present.

The map in figure 1 shows approximately how the air masses were distributed over the Eastern States and about the storm center on that date. On this chart, as on the others in this paper, cold fronts are indicated by heavy solid lines, and warm fronts by heavy dotted lines. The air masses are designated according to the classification of Willett. The positions of the fronts over the ocean are very uncertain. However, as will be seen from examination of the upper air data, these fronts must have been present somewhere off the coast, and even if they are placed 200 miles from their true position the present discussion will not be affected.

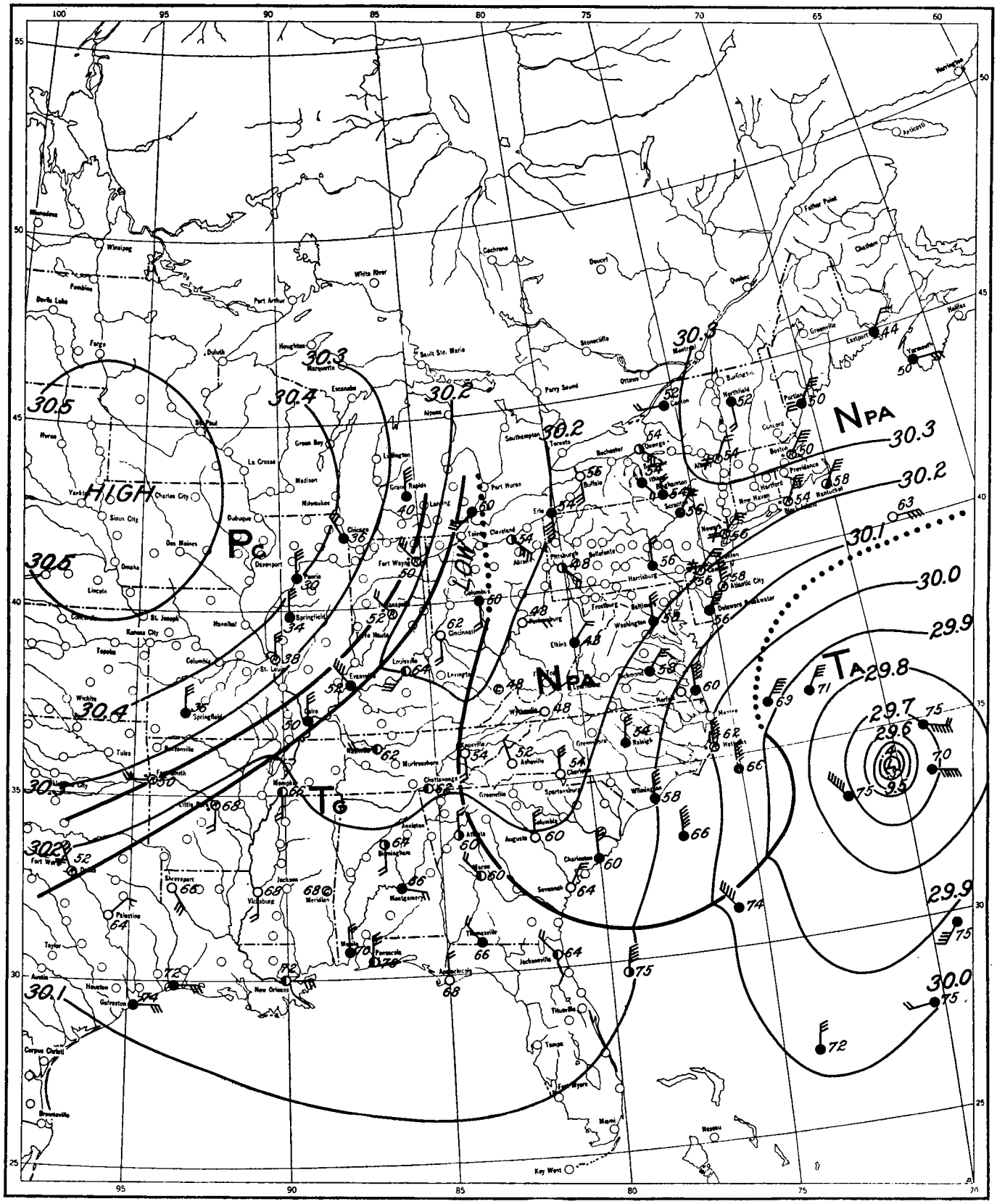

FIGURE 1.—Surface weather map, November 1, 1935, 8 a. m.

It is to be noted that N_{PA} (transitional polar Atlantic) air is flowing around the LOW center from the northeast and north, with the warm tropical Atlantic (T_A) air occupying most of the hurricane.

The vertical cross section through the atmosphere from Omaha eastward through several aerological stations (given in fig. 2) shows that along the Atlantic coast the two very distinct air masses, N_{PA} and T_A, were present. The airplane observation at Washington on that date indicated a relatively cold, moist current from the north which is identified as of polar Atlantic origin, and an unusually warm and moist air mass above which fits almost perfectly the qualitative and quantitative definitions of tropical Atlantic air. A pilot balloon observation at Washington earlier in the night further verified this analysis by showing that the latter current was coming from the east out of the region of tropical air designated on the surface chart, figure 1. The conditions indicated on the cross section to the east of Washington are extrapolated from the data of Mitchel Field, near New York, which is to the east but slightly to the north of the line of aerological stations chosen. If this extrapolation be correct, then Washington was to the west of the crest of the N_{PA} air, and therefore the T_A air above must have been moving downslope. This would then account for the absence of rain at Washington. Upward movement of the T_A probably was to be found only along the immediate coast and at sea.

With this air-mass structure in mind, a possible explanation can be seen for the peculiar rain distribution at Miami when the storm reached there; the absence of rain in appreciable amounts on the forward or western side of the center was particularly noted. It seems reasonable that the current of air of polar origin, which at Washington and New York was 1 to 2 kilometers in depth and probably deepening, played an important part, and that the hurricane, even when it reached Miami, did not consist entirely of tropical air. It also is reasonable to assume that the air of polar origin would occupy the zone of northerly winds on the westward and forward side of the center as it approached Miami. The inherent low moisture content of this air as compared with the normal hurricane air probably accounts in some measure for the peculiar rain distribution noted at that station.

The effect of the very dry tropical superior (T_S) air which was occupying much of the upper atmosphere over the eastern United States may also account for the relative lack of precipitation. This air was moving from

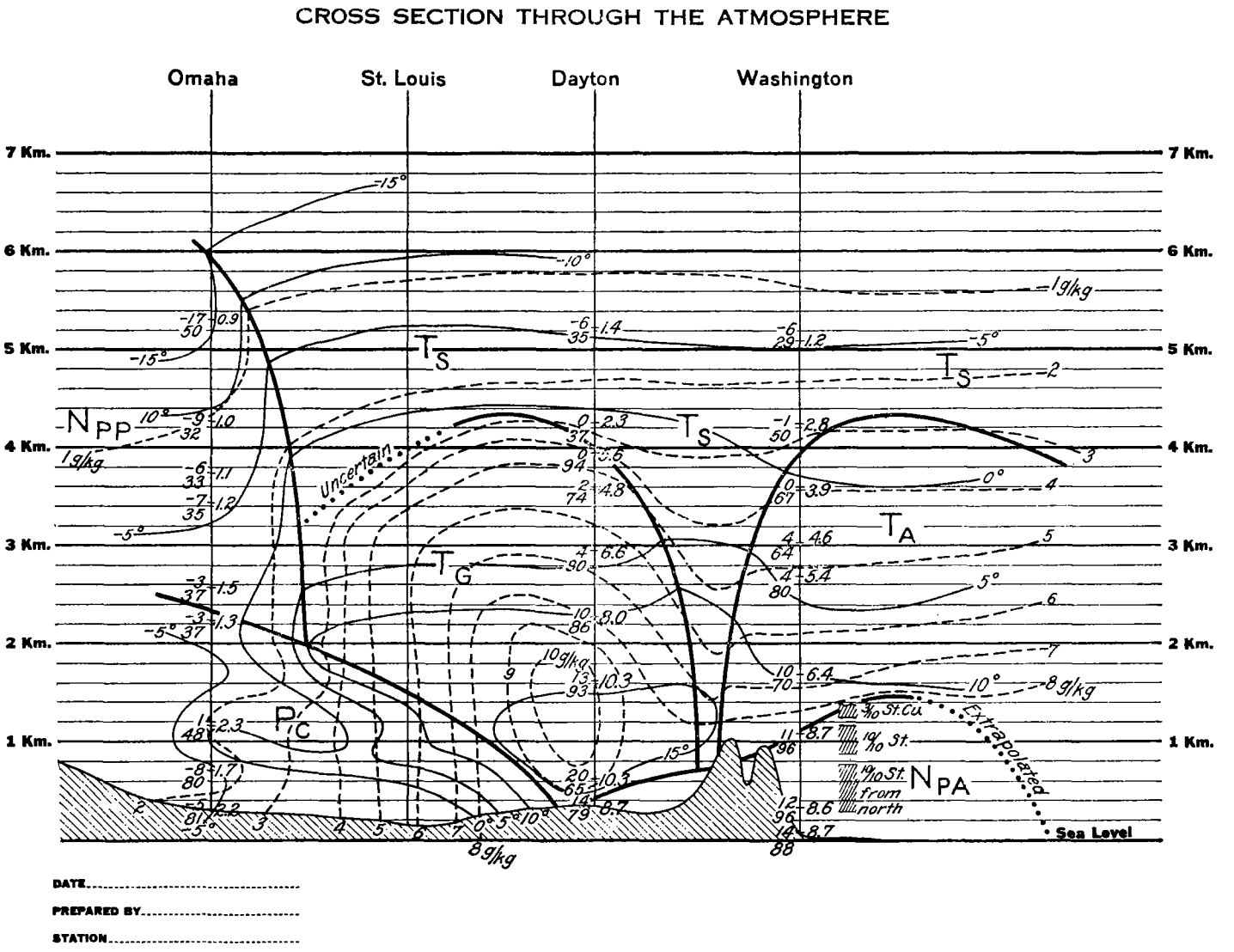

FIGURE 2.—Cross section of the atmosphere, Omaha to Washington, November 1, 1935. Figures to left of vertical lines are temperature and relative humidity (in that order) at the significant levels; figures to right are specific humidity.